SAI-82-553-HU

LEVEL 2

HWIL IR IMAGING TESTING

Final Report

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DISTRIBUTION: UNLIMITED

31 March 1981

PREPARED FOR:

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, AL 35898

U.S. ARMY MISSILE LABORATORY
Guidance and Control Directorate
Redstone Arsenal, AL 35898

March 31, 1981 SAI-82-553-HU

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Redstone Arsenal, AL 35898

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DAAK40-78-D-0011
Task 015

Dear Sir:

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If you have any questions, please contact the undersigned.

Sincerely,

SCIENCE APPLICATIONS, INC.

R. M. Chapman
Assistant Vice President

ja

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Army simulator facilities are presently configured to conduct hardware-in-the loop mission tasks on the HELLFIRE and COPPERHEAD missile systems. These systems presently use a LASER seeker. The facility is an ideal candidate to be converted to include infrared (IR) seekers used on the TGSM system. This study investigates the possibility and impact of a facility update.
This report documents the feasibility of developing a hardware-in-the-loop (HWIL) hybrid simulation incorporating infrared IR seekers used for the Assault Breaker

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program. Other hardware to be considered are the autopilot, signal conditioning, signal processing, and actuators which may be integrated into the system simulation. Considerations are given to replacing all or elements of hardware while substituting math models in the system simulation.

PREFACE

This report summarizes the work performed by Science Applications, Inc., under the technical direction of Mr. Larry R. Murdock, DRSMI-RGN. This work was performed for the Guidance and Control Directorate, U.S. Army Missile Laboratory, U.S. Army Missile Command, Redstone Arsenal, Alabama under Contract DAAK40-78-D-0011, Task Order No. 15. The period of performance was from November 10 1980 to March 31, 1981.

Prepared by:

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Approved by:

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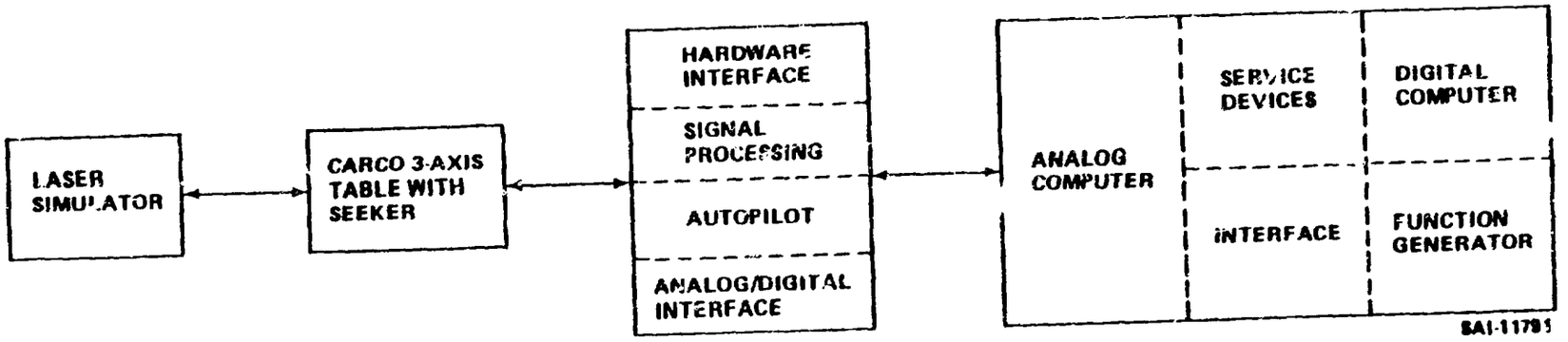
1. INTRODUCTION

This report presents an approach for a hybrid simulation of terminal homing missiles with infrared (IR) imaging seekers (IRIS). This approach is developed using the HELLFIRE version of the Laser Designator Weapon System (LDWS) hybrid simulation with hardware-in-the-loop (HWIL) capability and modifying it to interface with the IR Target Image Generator (IRTIG). The HELLFIRE simulation is currently operating on the SIGMA-5/COMCOR 5000 computers. A block diagram of the present LASER seeker HWIL hybrid simulation is shown in Figure 1-1.

Figure 1-2 illustrates the system structure of the proposed TGSM/IRTIG flow. The following sections will describe the IR scenarios and simulation methods to be implemented. It should be emphasized that the latest available HELLFIRE models are currently being used in the hybrid simulation.



NOTE: 1) SYSTEM SIMULATION HAS CAPABILITY TO SELECT ALL HARDWARE ELEMENTS OR ANY COMBINATION.
2) ALL HARDWARE ELEMENTS HAVE SOFTWARE (ANALOG/DIGITAL PROGRAMMED) ALTERNATES.

Figure 1-1. Hardware-in-the-Loop Hybrid Simulation for Laser Seeker Autopilot, Signal Processing, and Actuator Development and Test

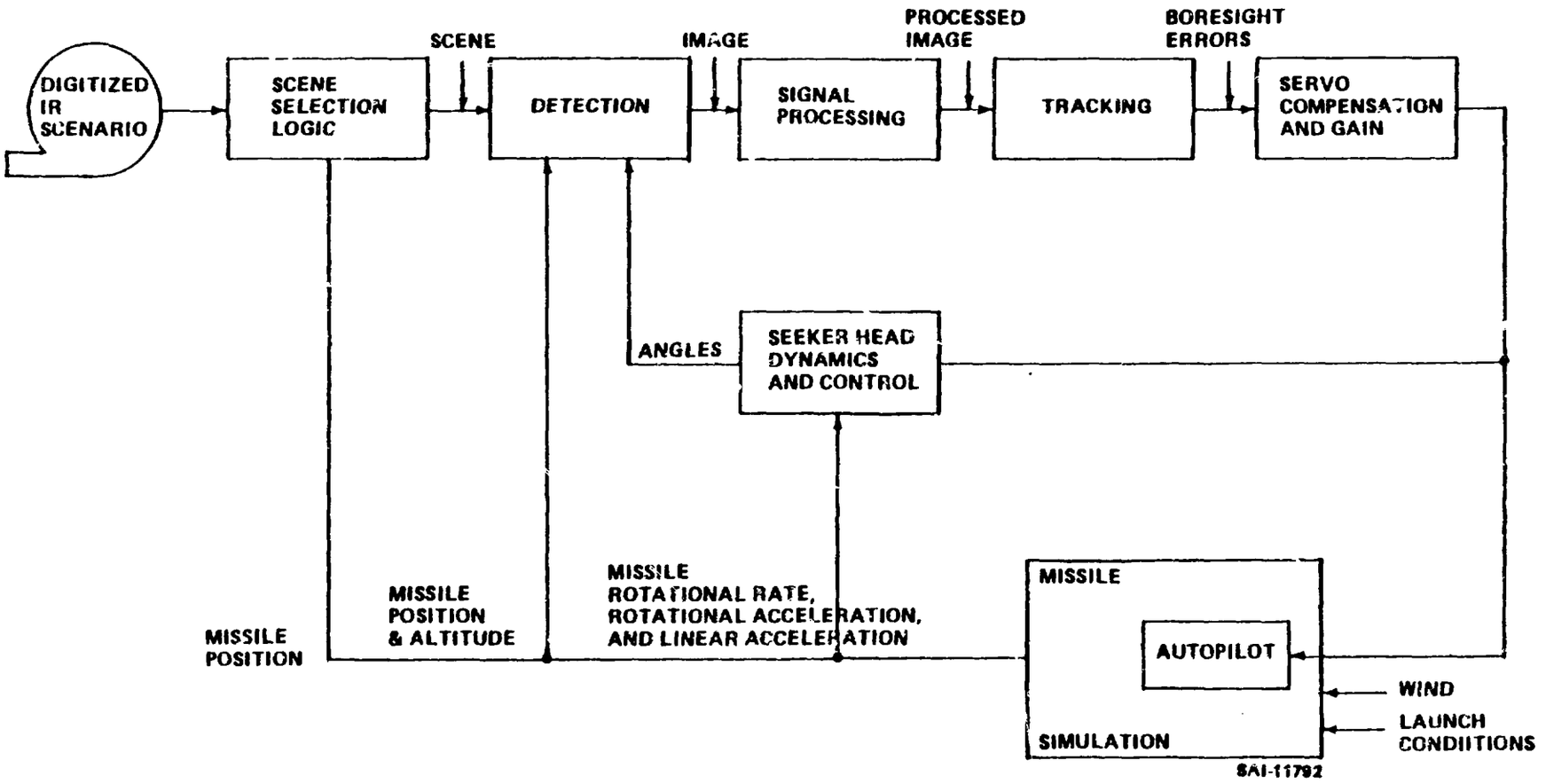


Figure 1-2. TGSM System with Target Imaging Generator Using HELLFIRE Math Modeling Where Applicable

2. HYBRID SIMULATION SYSTEM DISCUSSION

The simulation has the ability to operate TGSM hardware with the hybrid simulation. The HWIL capability will include the IR seeker, autopilot, signal conditioning, signal processing, and actuators which will be integrated into the system simulation. Programmed math models are also available to substitute when any or all elements of TGSM hardware are not used. When the hardware IR seeker is used an IR Target Imaging Generator (IRTIG) provides the target and background scenarios; when the IR math model is used, an all-digital model produces the target generation scenario. Further discussion of the targeting scenarios will be conducted in Section III.

The simulation equipment consists of a Sigma-5 digital computer with 64K words of memory, an AD-10 multiprocessor with four processors supported by 4K of program memory and 16K of data memory, two Ci5000 and one EAI23IE analog computers, analog/digital interface, and trunk interface, and 6-DOF Carco table which will support the IRTIG and TGSM hardware elements. A simulation hardware flow diagram is shown in Figure 2-1 with the proposed IRTIG and TGSM hardware included. No hardware/software timing problems are anticipated based on past experience with the HELLFIRE and COPPERHEAD HWIL tasks.

The simulator techniques used to perform the simulation tasks combine the computational efficiency required for weapon system analysis with sufficient modeling, detail to expose flaws, and suggest improvements in missile subsystem design.

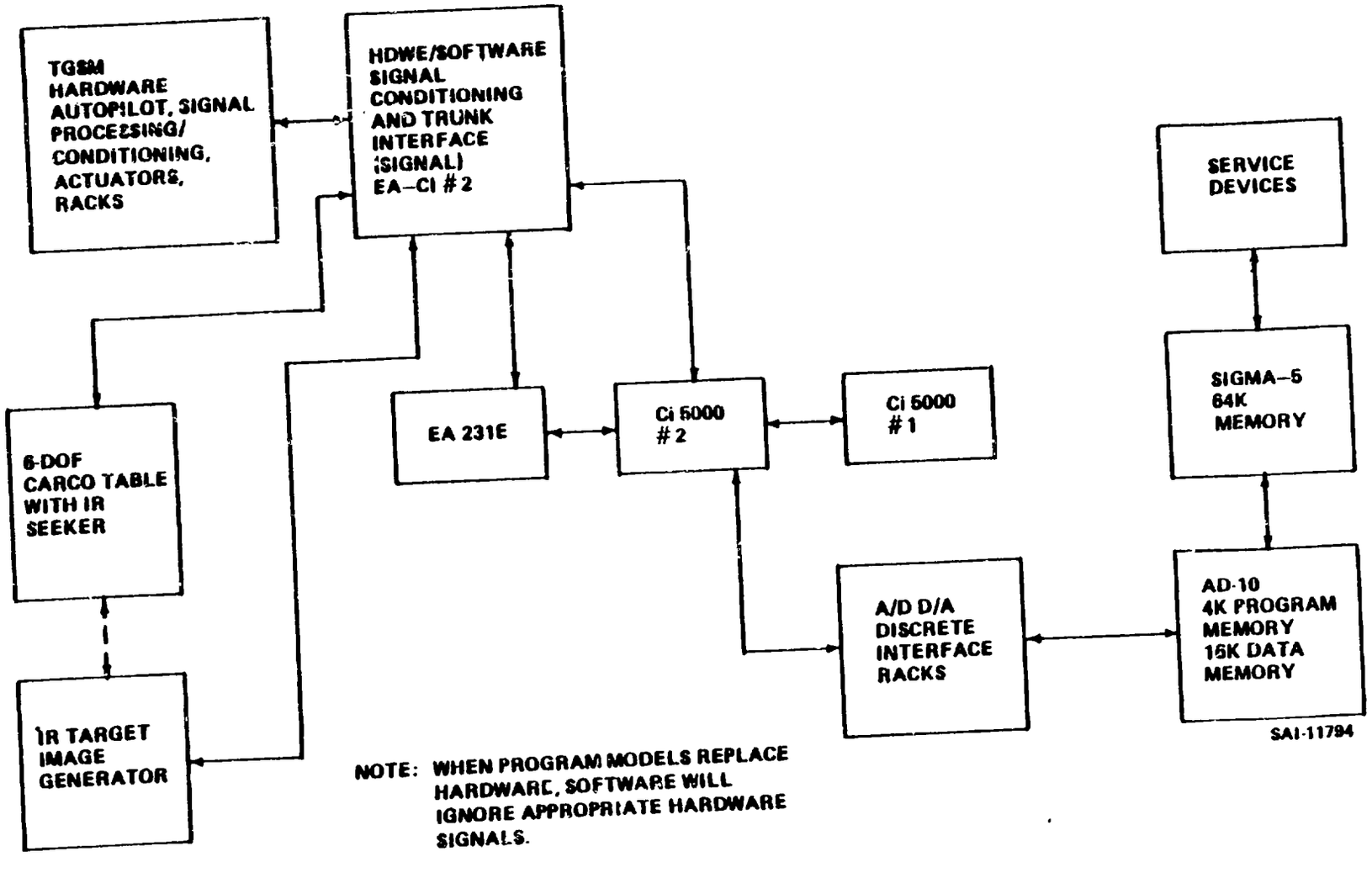


Figure 2-1. Hardware/Software Flow Diagram

3. INFRARED IMAGING

3.1 HARDWARE

An IR Target Imaging Generator (IRTIG) has been developed by Science Applications, Inc. Report No. SAI-81-765-HU dated November 1980. This equipment realisticaly generates target and background scenarios for stationary and moving targets for a number of target conditions. The IRTIG will be integrated to the TGSM hardware and program models via signal conditioning, hardware/software, and interface racks to provide total system control. This will provide the capability to perform target selection and homing from dispersion to impact and will maintain a thirty-two channel analog record of the flight. Figure 3-1 shows an IRTIG configuration diagram.

3.2 SIMULATED

When IR seeker hardware is not being used, a digital program model is available. An IR scenario consisting of a sequence of two-dimensional scenes will be used. The appropriate scene for a given point in flight is selected based on missile-to-target range. In determining the probability-of-hit for a given engagement, the HELLFIRE Monte Carlo will be used to vary launch conditions, etc. The 6-DOF missile and the seekers 2-DOF will be simulated from launch to impact. The IR scenarios used with the simulation will be derived from two sources: (1) math model, and (2) radar data/IR video data obtained from flight data. A typical flight will cover 1 to 3 KM in approximately 10 seconds.

The numerical integrations for the missile and seeker head will be done separately so that the missile computations are not bound by the small stepsize required by the seeker head higher-frequency dynamics. Detection across the seeker field-of-view (FOV) will be divided into segments, with movement of the seeker head occurring between segments. Thus, the blurring effect of the seeker head motion will be simulated in a quantified way.

The missile integration stepsize and the time between detection segments will be selected to harmonize with each other and with the tracking update interval (Figure 3-2). For each missile integration step, the initial and final states of the vehicle will be used to construct approximations state within

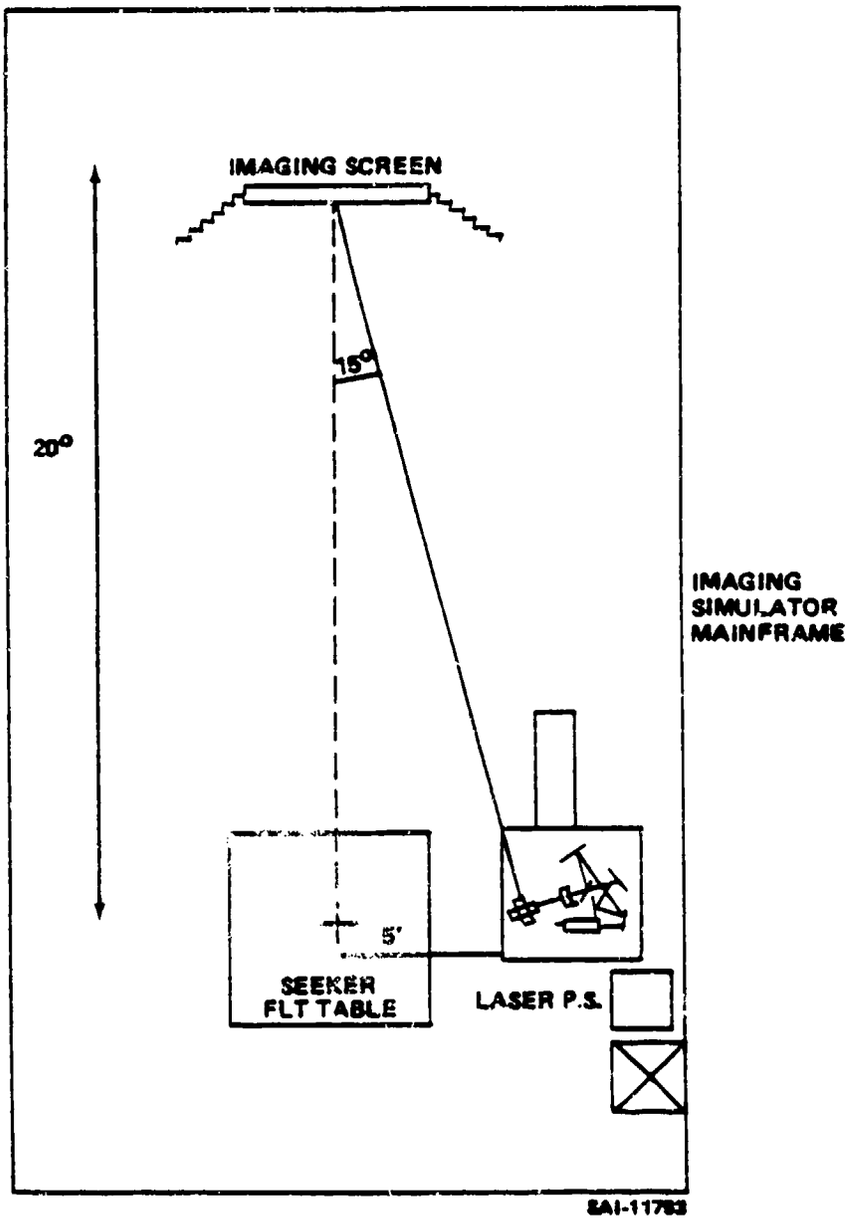


Figure 3-1. IR Target Imaging Generator

the integration interval. These approximations are used in the seeker head integration and detection computations. A new target scene will be selected for each integration step. During the seeker head integration step, the FOV will be updated and scan cycle performed (Figure 3-3). After the missile integration steps have been completed, and a detection field has been completed, the resultant detector array will be fed into the signal conditioning/processing and tracking computations (hardware/software). The outputs will be the calculated pitch and yaw boresight errors. Updates in the calculated boresight errors will be made after each tracking interval. Each detection field is divided into several detection segments, with seeker head motion occurring between segments. For each segment, the detector outputs for the appropriate portion of the seeker FOV will be computed. These computations will be used to project the seeker FOV onto the tarfet plane. Figure 3-4 defines the geometry and variables used in projecting the seeker FOV onto the target plane. The angles α, β, and ϕ define the angular position and orientation of the seeker field of view on the target plane.

Figure 3-2. Seeker Missile Integration Steps

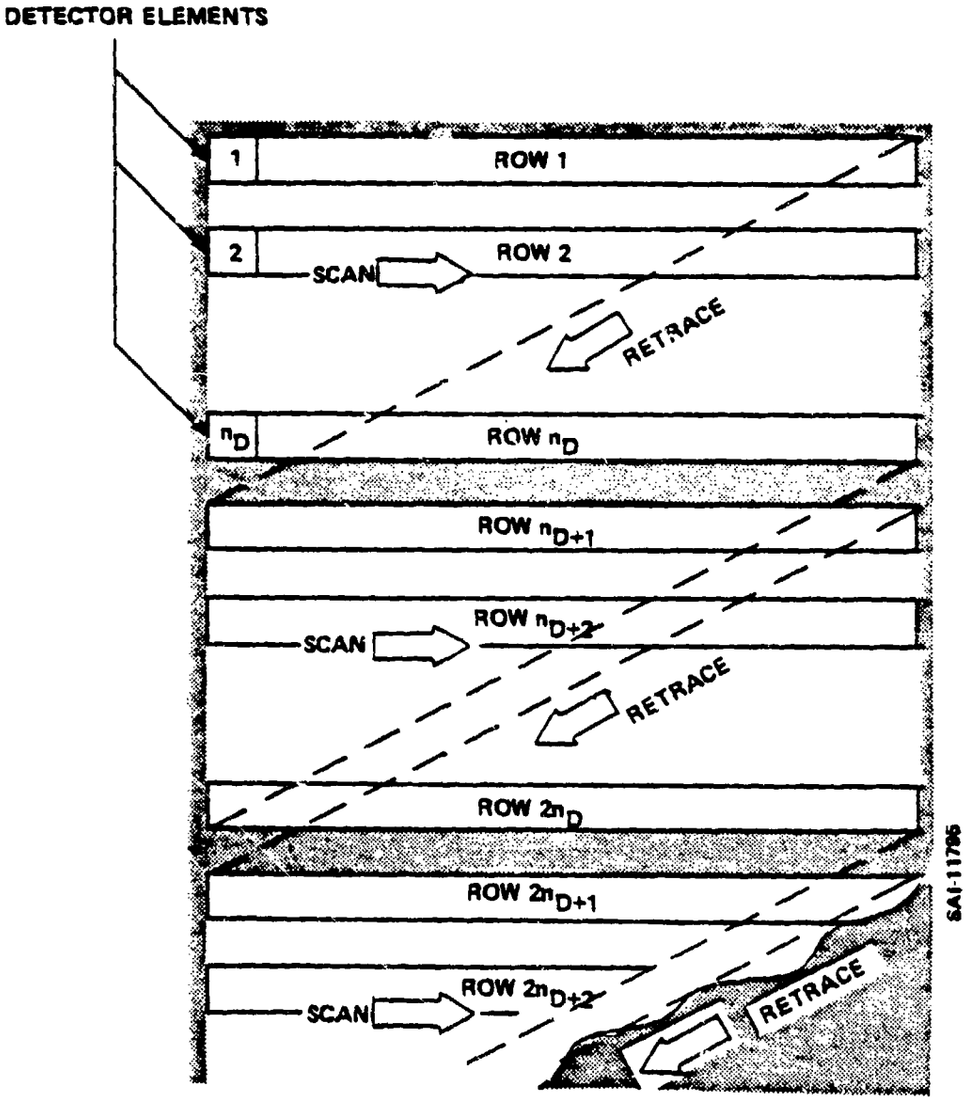


Figure 3-3. Raster Scan Pattern

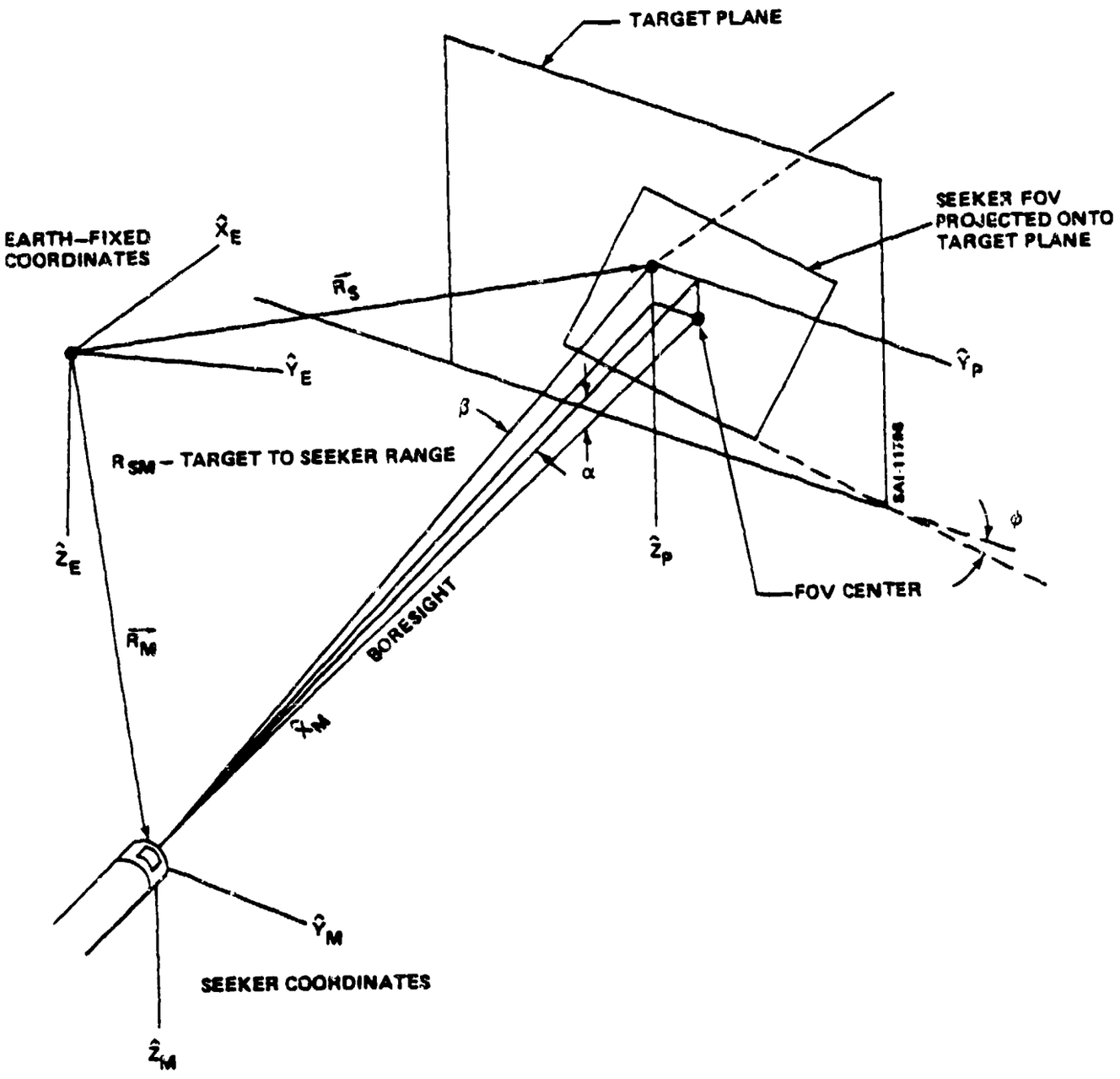


Figure 3-4. Seeker Target Reference Coordinates to Locate Missile Position and Altitude Relative to Target and Seeker FOV

4. TGSM HARDWARE SOFTWARE EXCHANGE

The hybrid simulation is developed to interface with TGSM hardware elements or programmed math models. Hardware elements of the weapons system are: 1) infrared seeker, 2) autopilot, 3) actuators, 4) signal conditioning, and 5) signal processing. The system simulation has the ability to operate with all elements or any combination of these with the appropriate programmed math models.

5. MODELING DISCUSSION

The program models developed for HELLFIRE will, in general, suffice. Where necessary, modifications to existing programs will be performed using data furnished by the generating sources. The basic programmed models will be:

- Body dynamics with thrust vectors
- Aerodynamics with related wind to body angles
- Autopilot (to be used only when hardware not active)
- Signal conditioning/processing (to be used only when hardware not active)
- Actuators (to be used only when hardware not active)
- IR seeker (scan or storing) (to be used only when hardware not active)
- Gyro-to-body relationship
- Inertial body/target reference
- Missile-to-target relationship (search and homing)

These program models will be developed in modular form to easily permit data updates, parametric printouts at completion of test for evaluation and program updates.

6. CONCLUSIONS

The Guidance and Control Hybrid Computer Facility is presently performing HWIL terminal homing exercises for a multitude of scenarios using Monte Carlo test selection. With the addition of the IRTIG, the facility will be easily adaptable to the TGSM hardware. A minimum of interfacing will be required between the analog computers and the hardware. The TGSM HWIL/programmed math models will have the capability of performing simulated flight exercises from dispersion to impact on stationary or moving targets with a variety of background environmental conditions such as bushes, trees, etc. using independent or Monte Carlo test selection. The analysis performed on the tests will assist in both seeker verification to specifications and for suggestions in system/subsystem design.

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

LIST	NAME
FOV	Field-of-View
HWIL	Hardware-in-the-loop
IR	Infrared
IRIS	Infrared Imaging Seekres
IRTIG	Infrared Target Imaging Generator
LDWS	Laser Designator Weapon System
TGSM	Terminal Guided Submissile

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